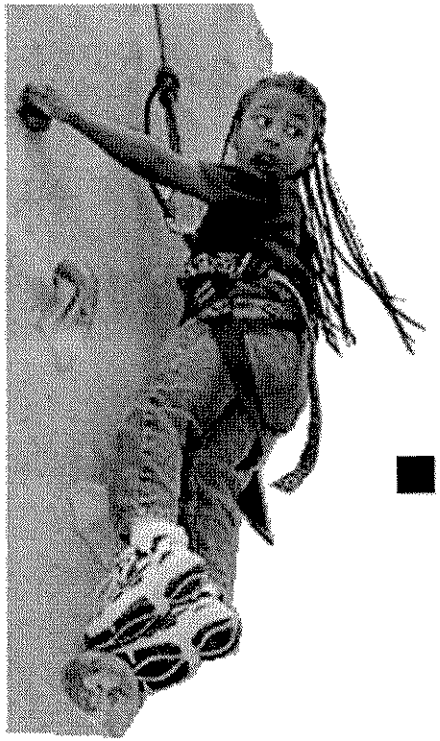
Lecture

4/19/05

Outline

- Light as waves
  - Huygens' Principle
  - Interference

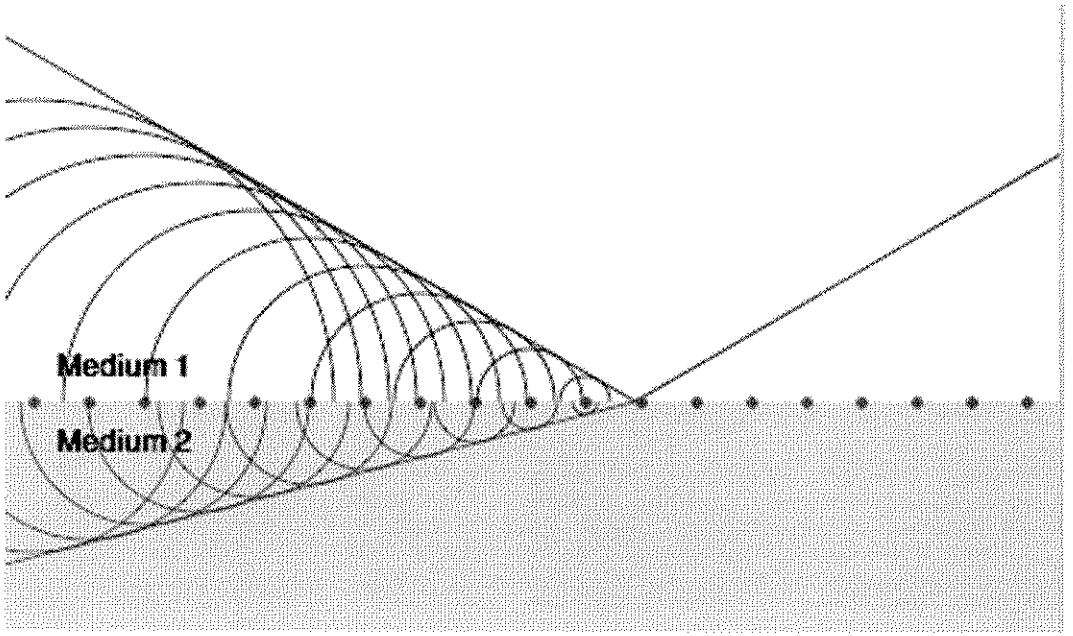


Foothold wave ideas: Huygens' Principle

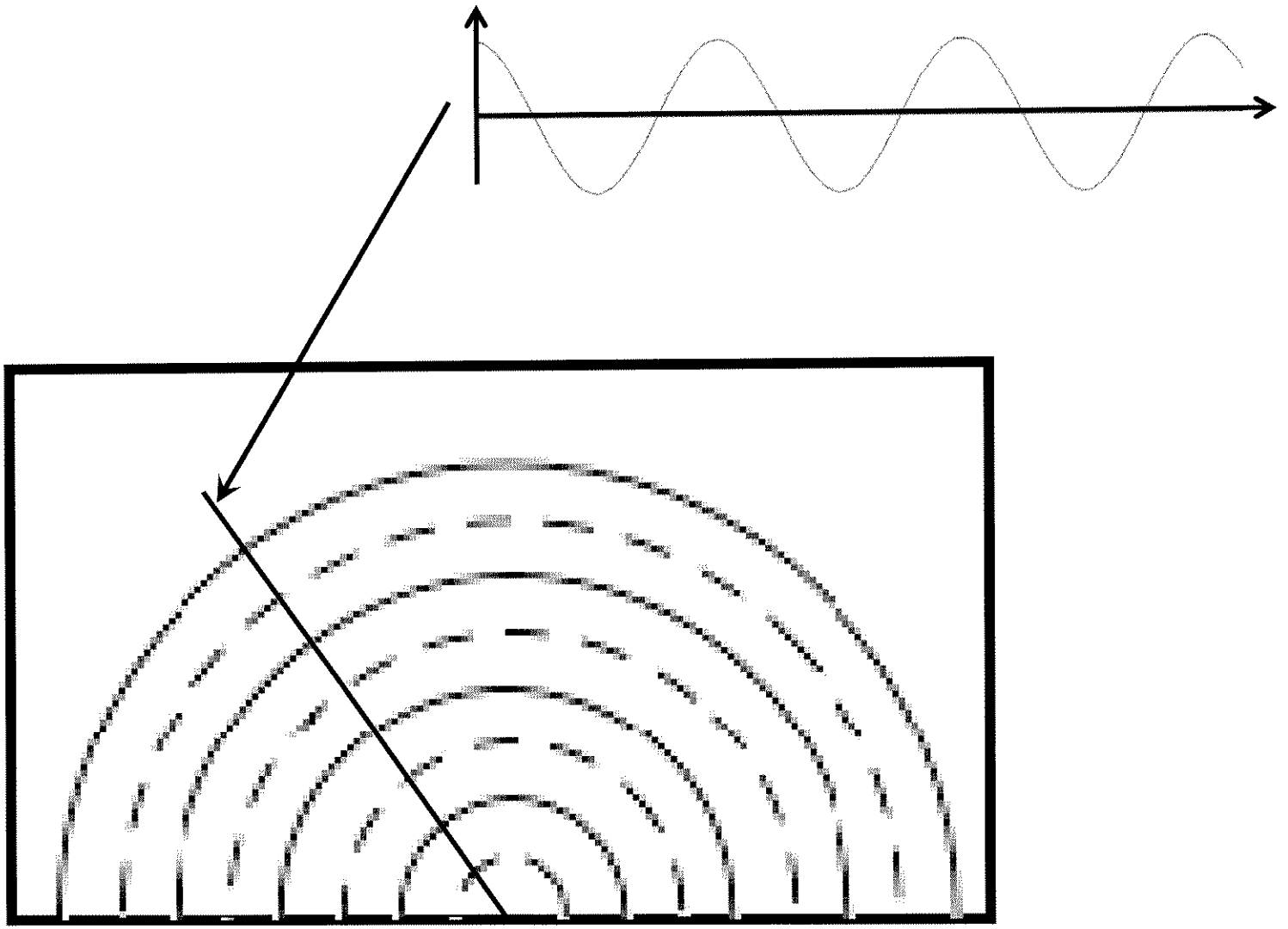
- The critical structure for waves are the lines or surfaces of equal amplitude: wavefronts.
- Each point on the surface of a wavefront acts as a point source for outgoing spherical waves (wavelets).
- The sum of the wavelets produces a new wavefront.

- Huygens' principle satisfactorily explains both the reflection and refraction principles (just as Newton's particle model does).
- In Huygens' wave model, light travels slower in dense media.

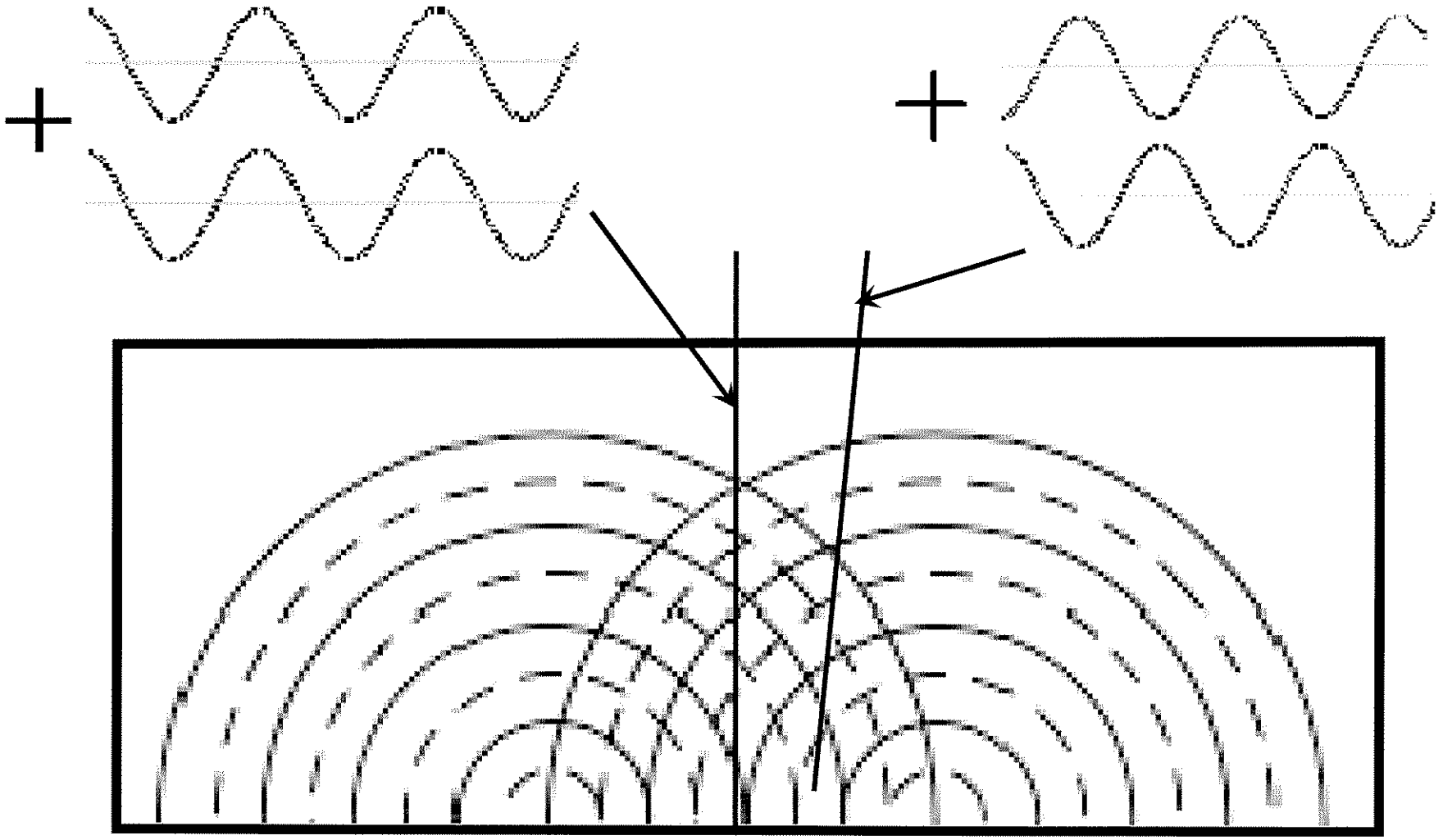
$$n = \frac{c}{v}$$



Ripple tank with 1 source

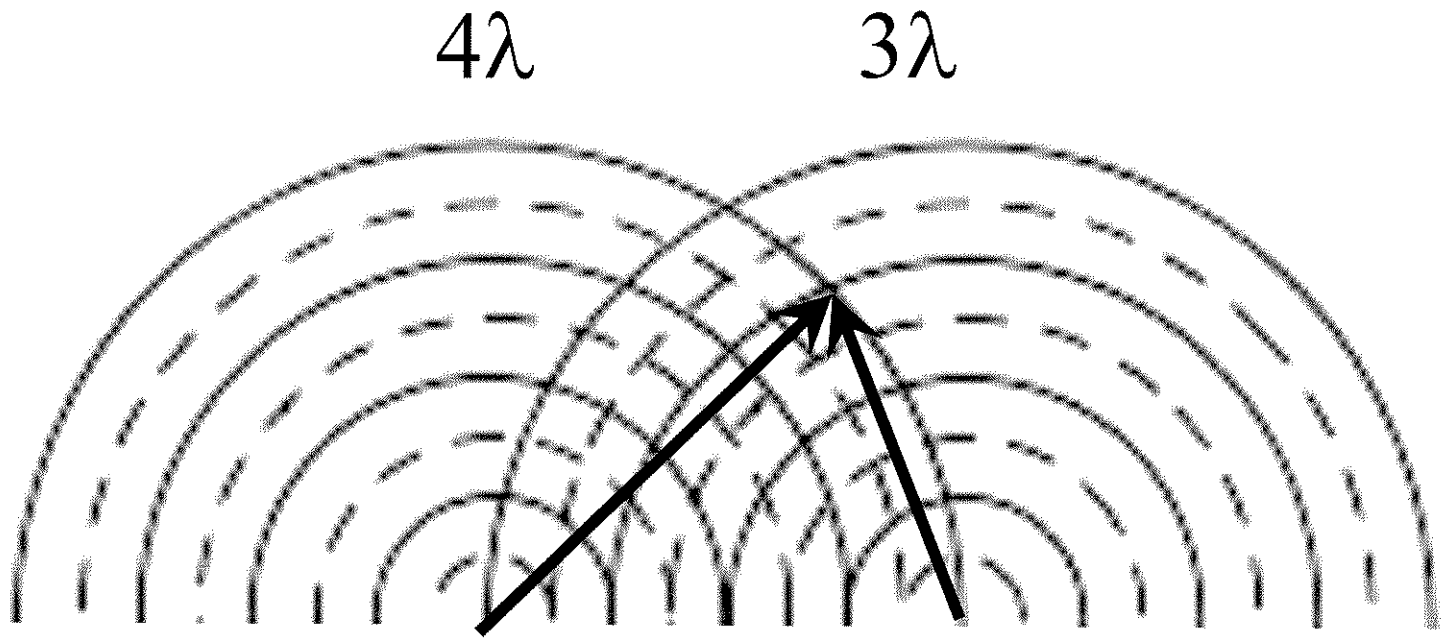


Ripple tank with 2 sources



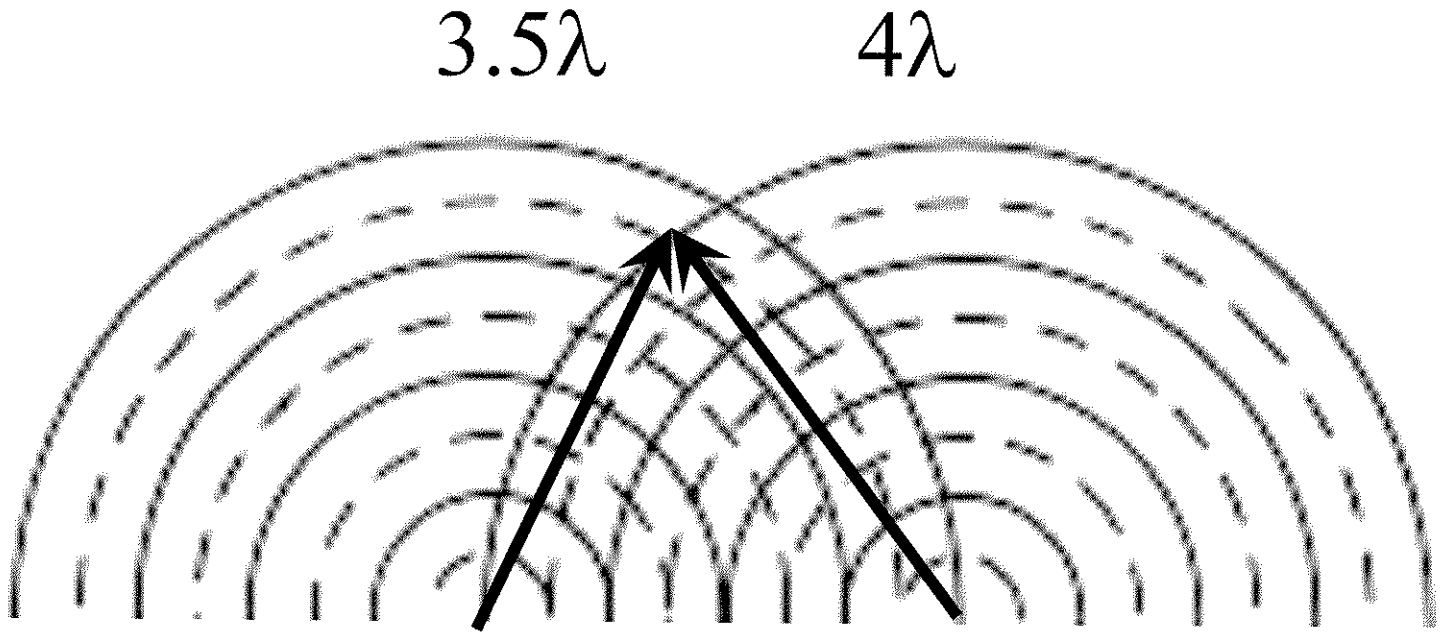
Path difference

- The critical point is how far is the point under consideration from each of the sources.



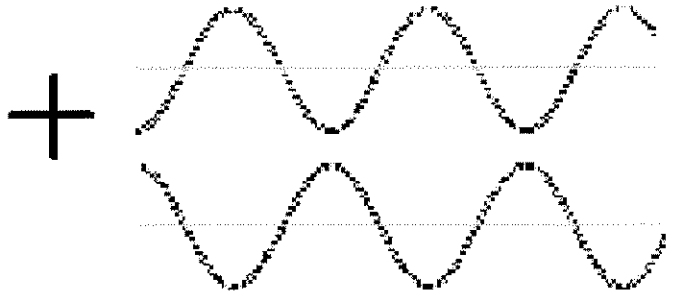
Path difference

- The critical point is how far is the point under consideration from each of the sources.

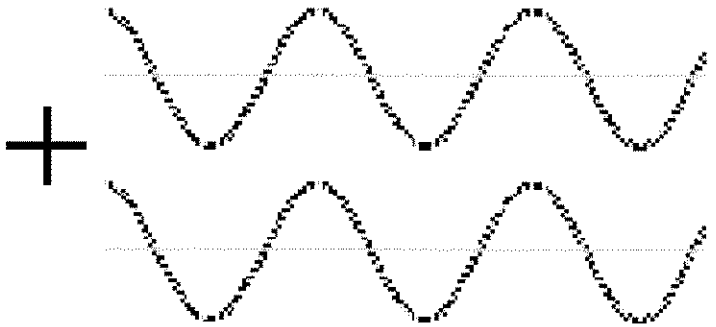


Path difference

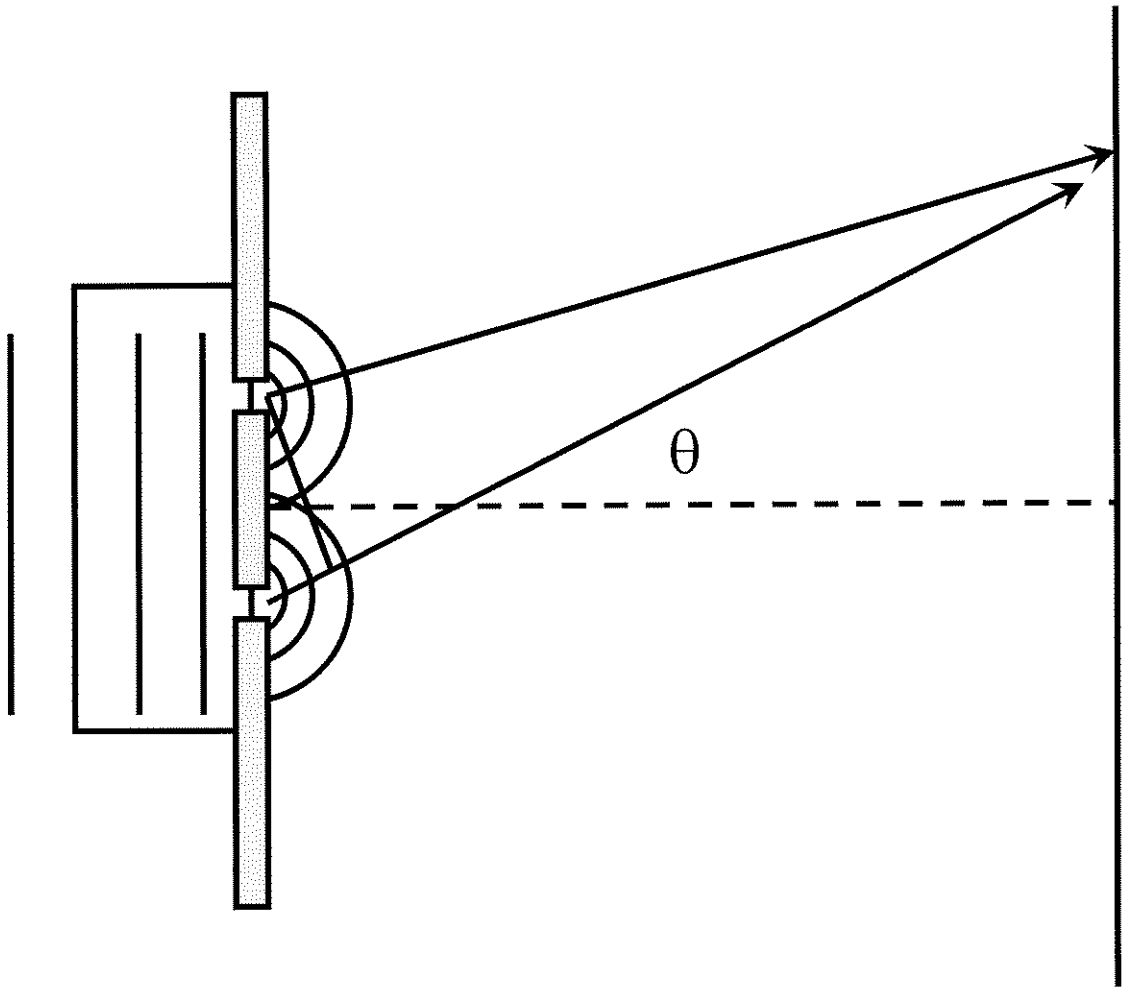
- When $\Delta D = n\lambda$, the waves add.

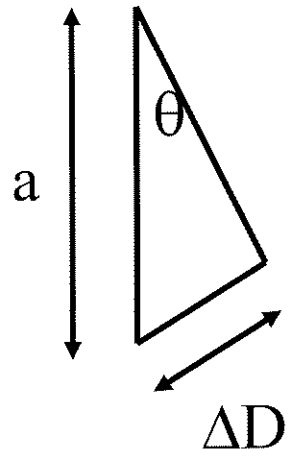


- When $\Delta D = (n+1/2)\,\lambda$, the waves cancel.



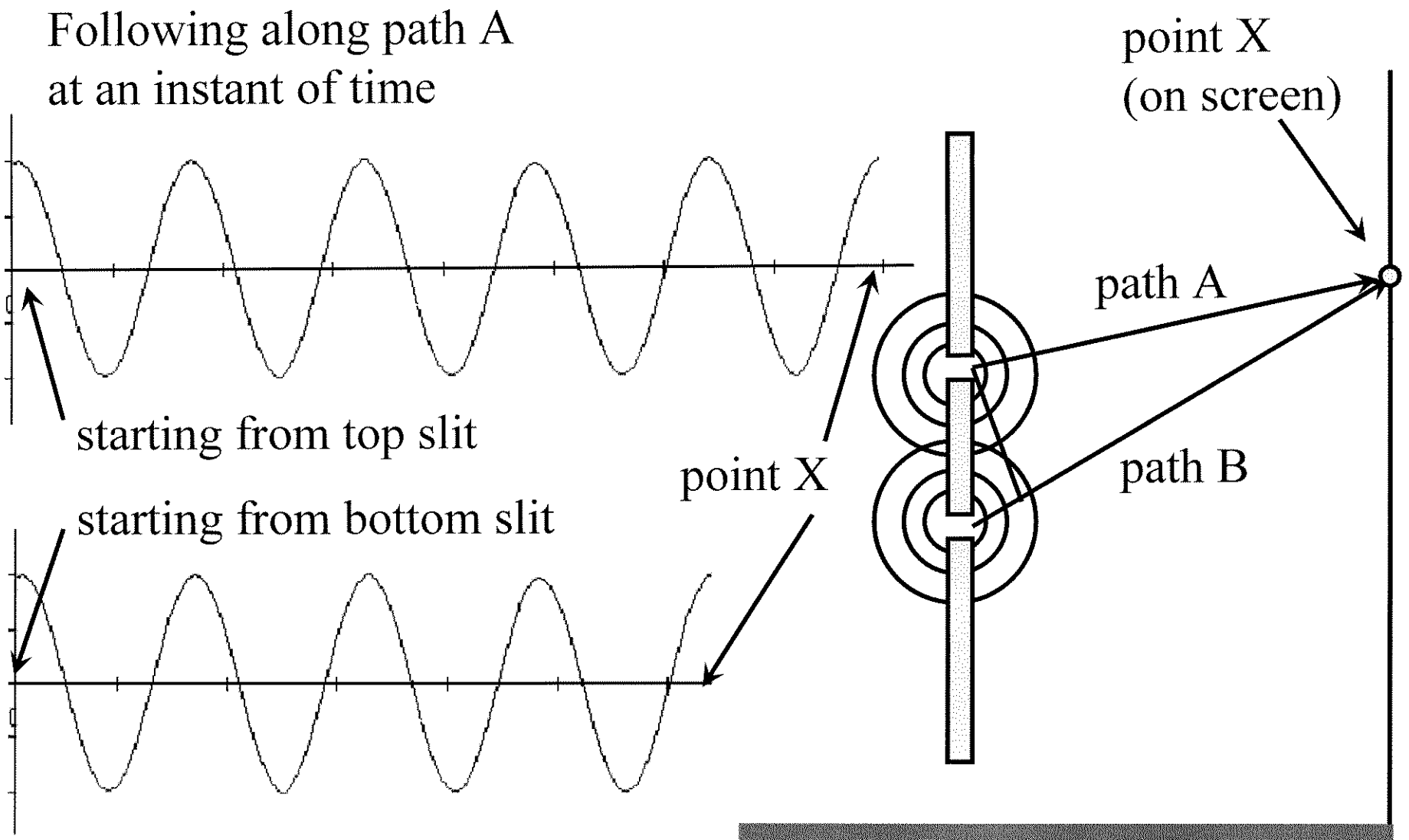
A First Test: Interference

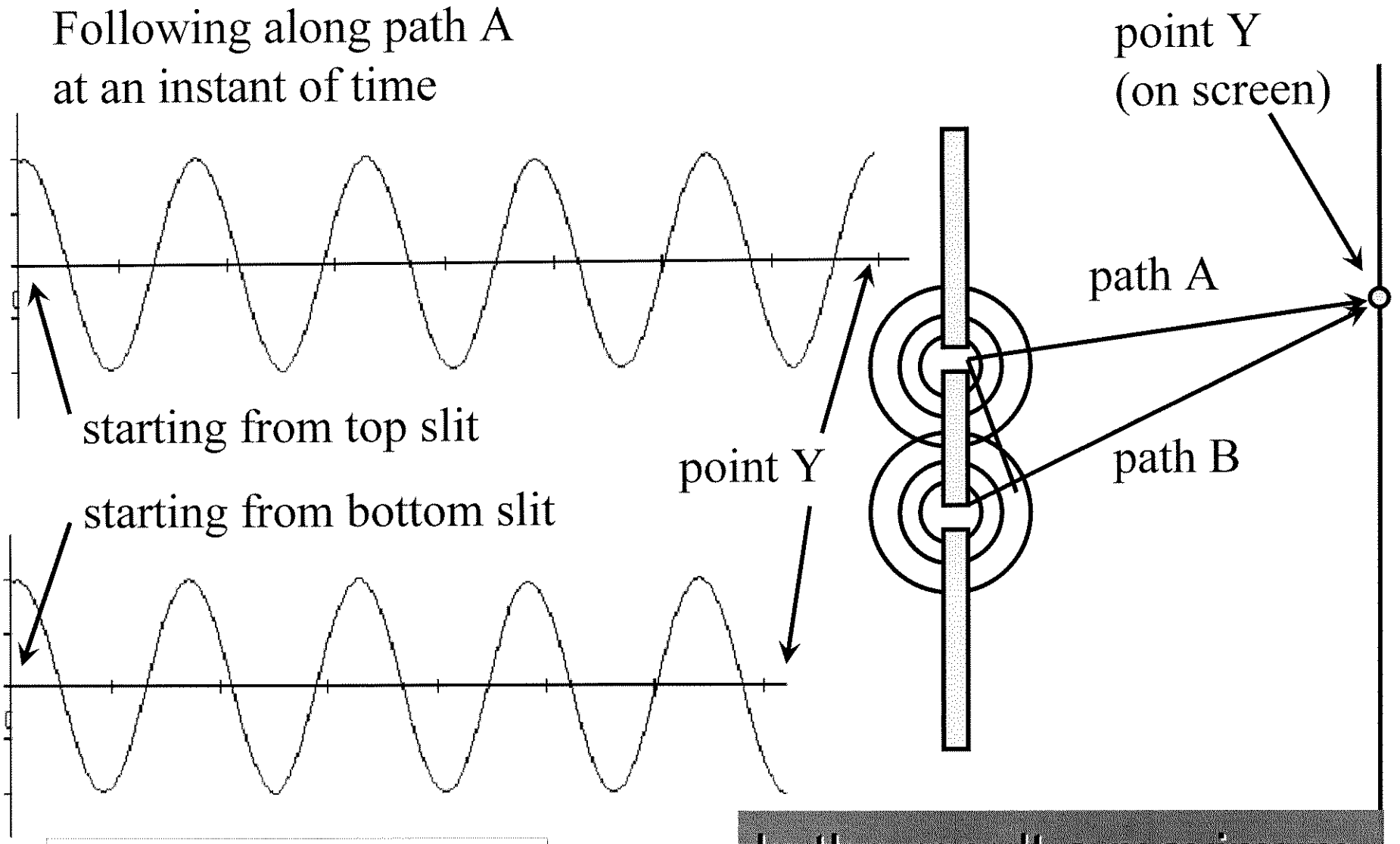




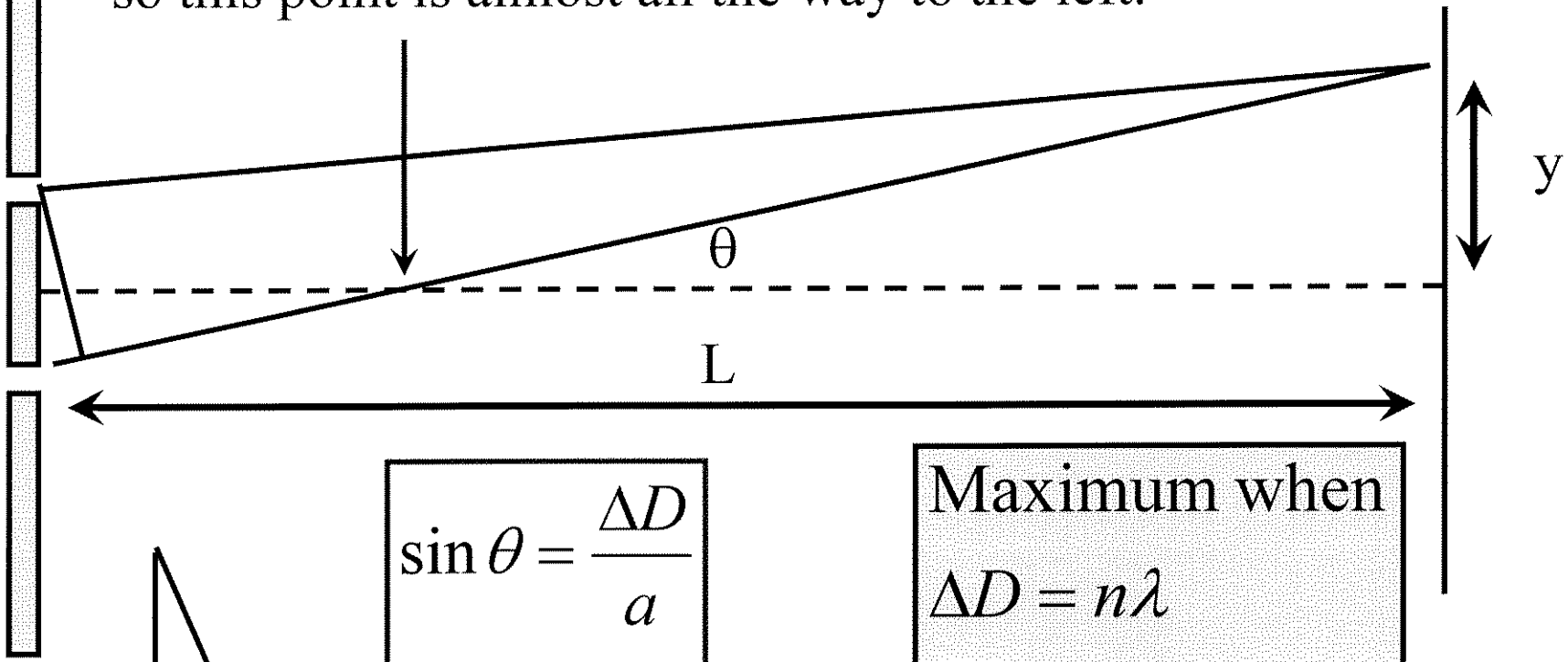
When $\Delta D = n\lambda$, waves add.

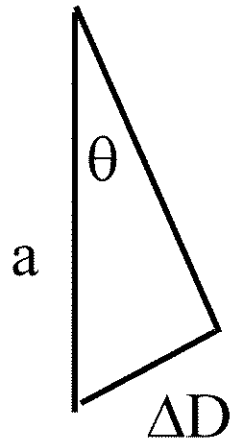
When $\Delta D = (n+1/2)\lambda$, waves cancel


Following along path A
at an instant of time
point X
(on screen)
path A
starting from top slit
point X
path B
starting from bottom slit
Following along path B
at an instant of time
Is the result a maximum,
minimum, or neither?


Following along path A
at an instant of time
point Y
(on screen)
path A
path B
starting from top slit
point Y
starting from bottom slit
Following along path B
at an instant of time
Is the result a maximum,
minimum, or neither?

Slits are really much, much closer than shown
so this point is almost all the way to the left.





$$\sin\theta = \frac{\Delta D}{a}$$

$$\tan\theta = \frac{y}{L}$$

Maximum when

$\Delta D = n\lambda$

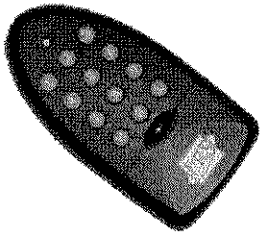
Minimum when

$\Delta D = (n + \frac{1}{2})\lambda$

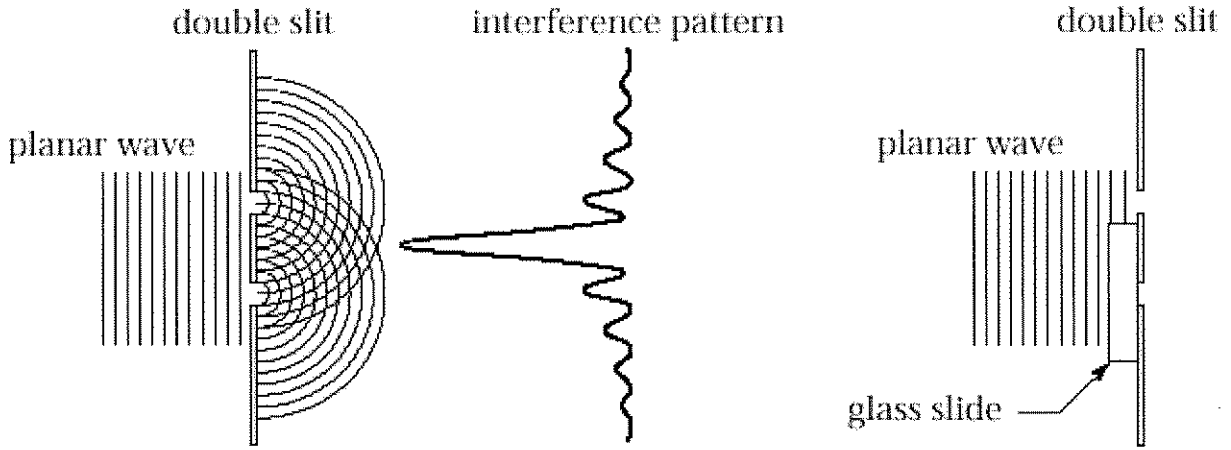
For small angles,
$\sin\theta \approx \tan\theta \approx \theta$

$$\Rightarrow \quad \frac{\Delta D}{a} = \frac{y}{L}$$

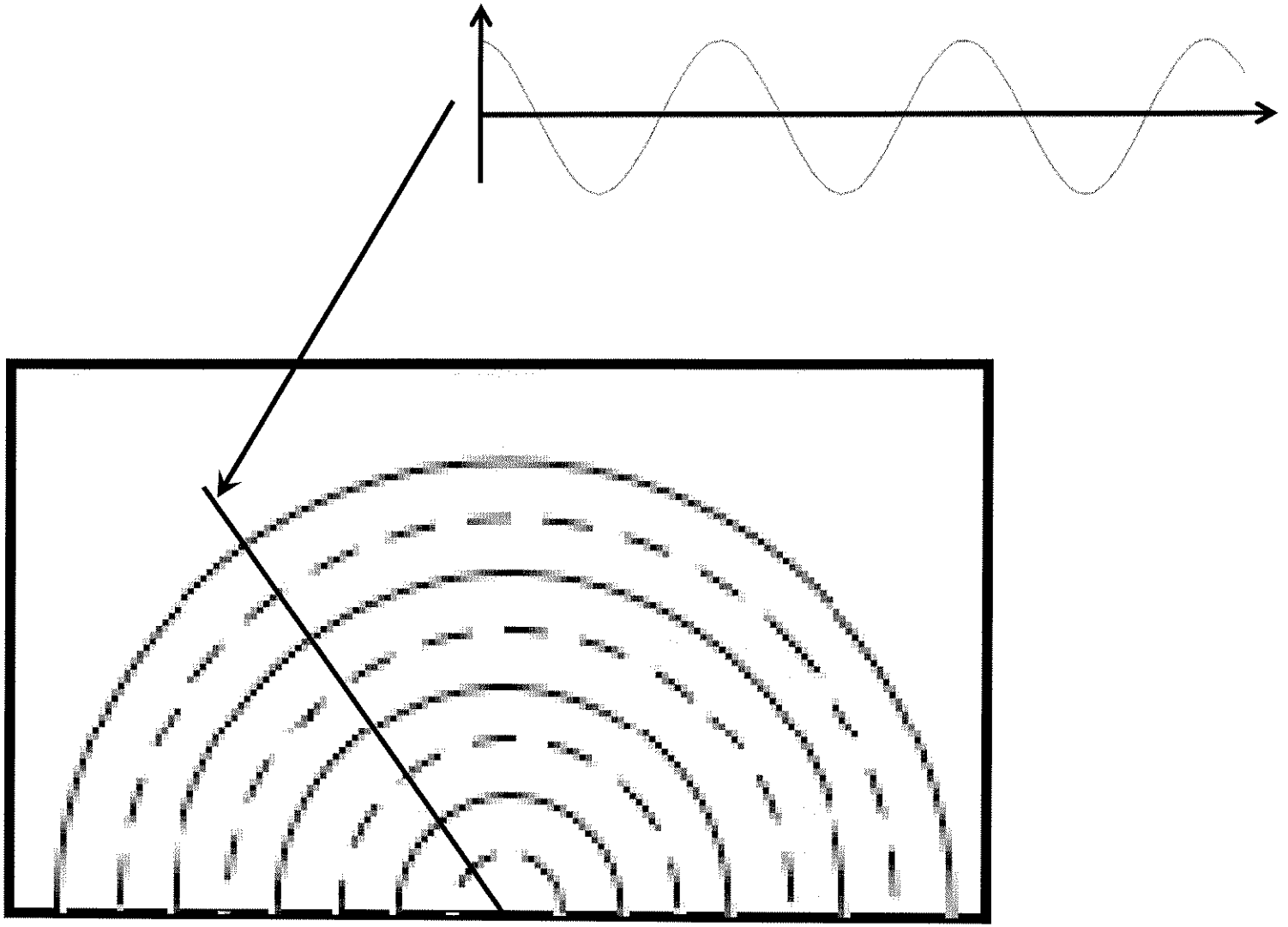
Puzzle



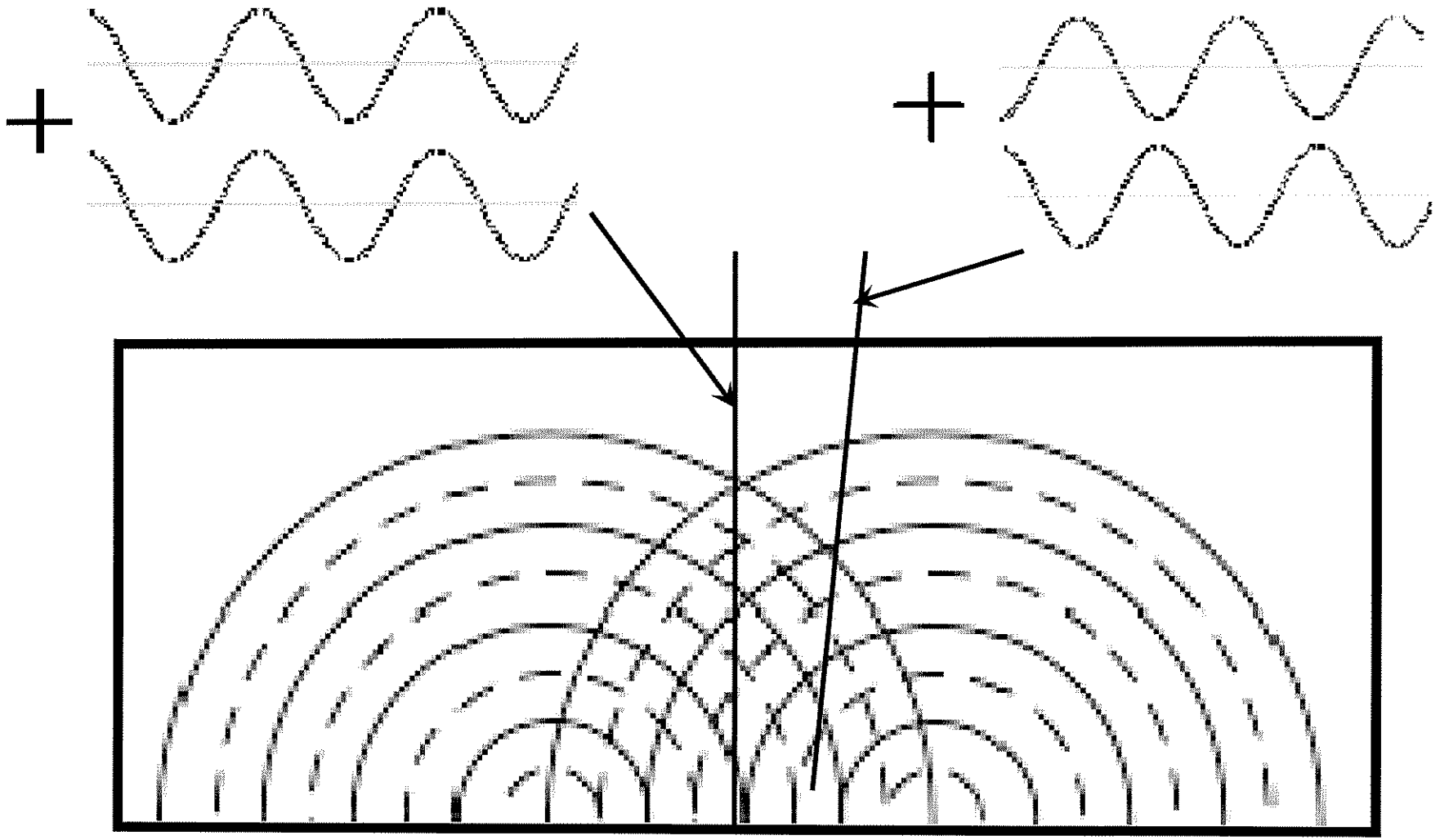
- An interference pattern is formed by a double-slit. If we cover one slit with a glass plate, the phases of the two emerging waves change because λ is shorter in glass than in air. If the phase difference is 180°, how is the interference pattern changed?



Ripple tank with 1 source

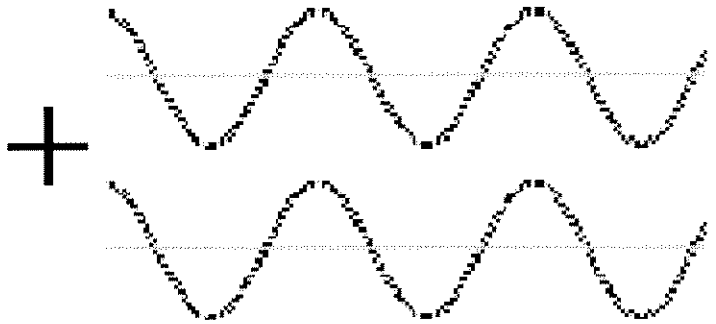


Ripple tank with 2 sources

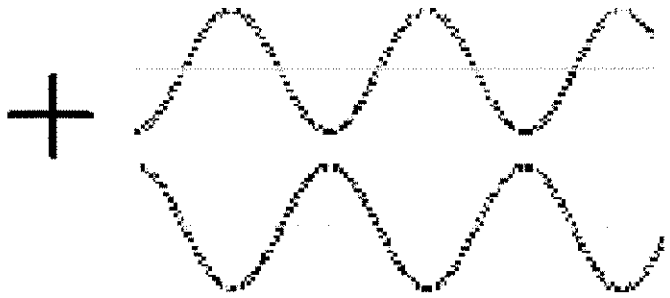


Path difference

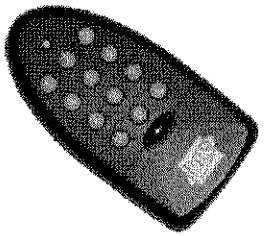
- When $\Delta D = n\lambda$, the waves add.



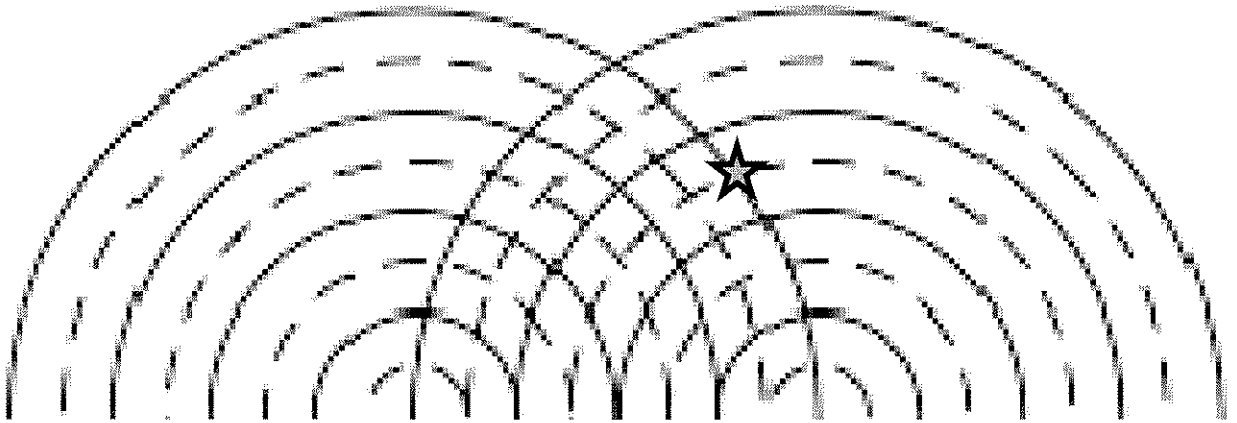
- When $\Delta D = (n+1/2)\,\lambda$, the waves cancel.



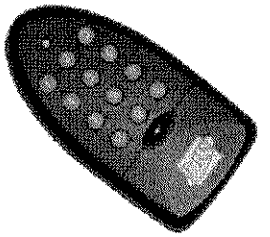
Puzzle



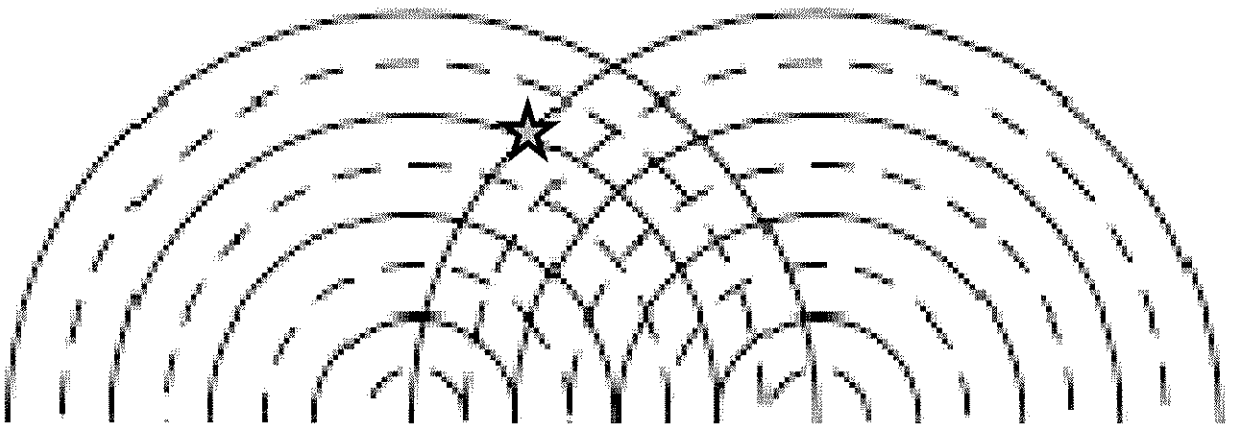
- Shown below are ripples produced by two in-phase tappers in a ripple tank. A small cork placed at the gold star will
  - 1. Move outward
  - 2. Stay stationary
  - 3. Bob up and down the same amount as it would with one tapper.
  - 4. Bob up and down more than it would with one tapper.
  - 5. Bob up and down less than it would with one tapper.
  - 6. Do something else.



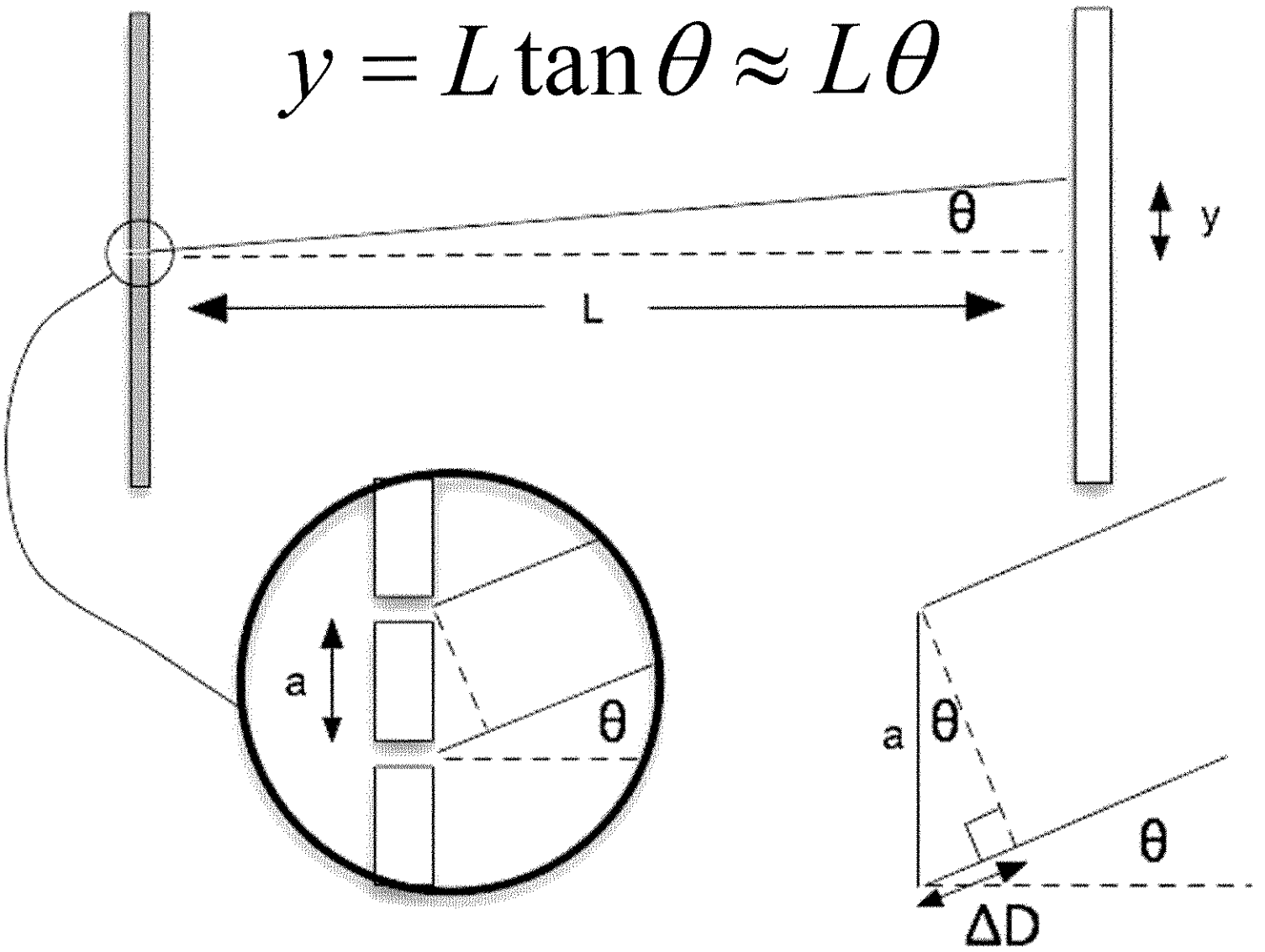
Puzzle



- Shown below are ripples produced by two in-phase tappers in a ripple tank. A small cork placed at the gold star will
  - 1. Move outward
  - 2. Stay stationary
  - 3. Bob up and down the same amount as it would with one tapper.
  - 4. Bob up and down more than it would with one tapper.
  - 5. Bob up and down less than it would with one tapper.
  - 6. Do something else.



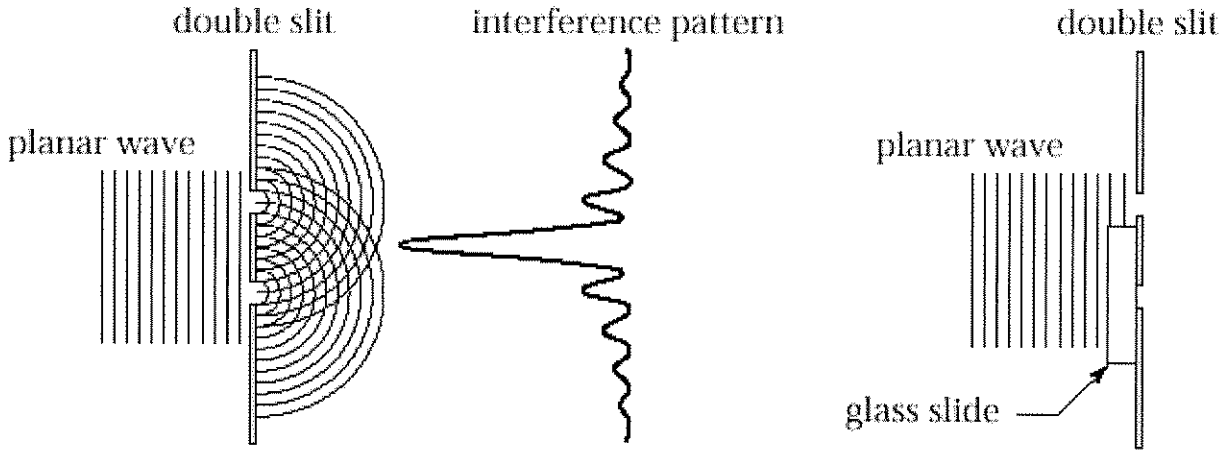
$$y = L\tan\theta \approx L\theta$$



$$\Delta D = a\sin\theta \approx a\theta$$

Puzzle

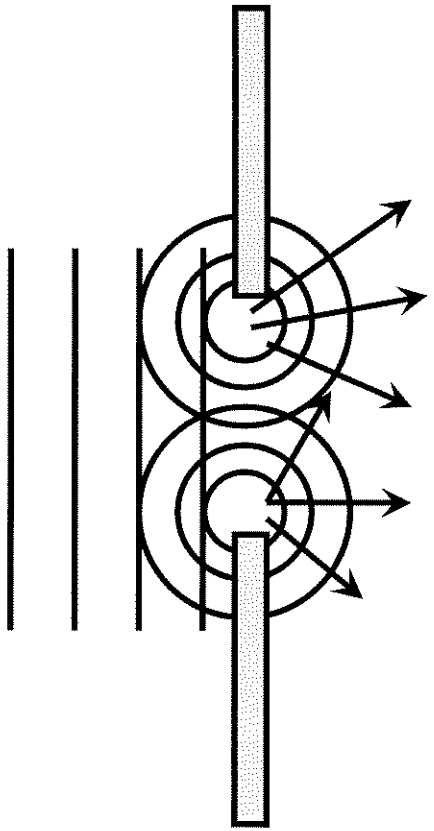
- An interference pattern is formed by a double-slit. If we cover one slit with a glass plate, the phases of the two emerging waves change because λ is shorter in glass than in air. If the phase difference is 180°, how is the interference pattern changed?



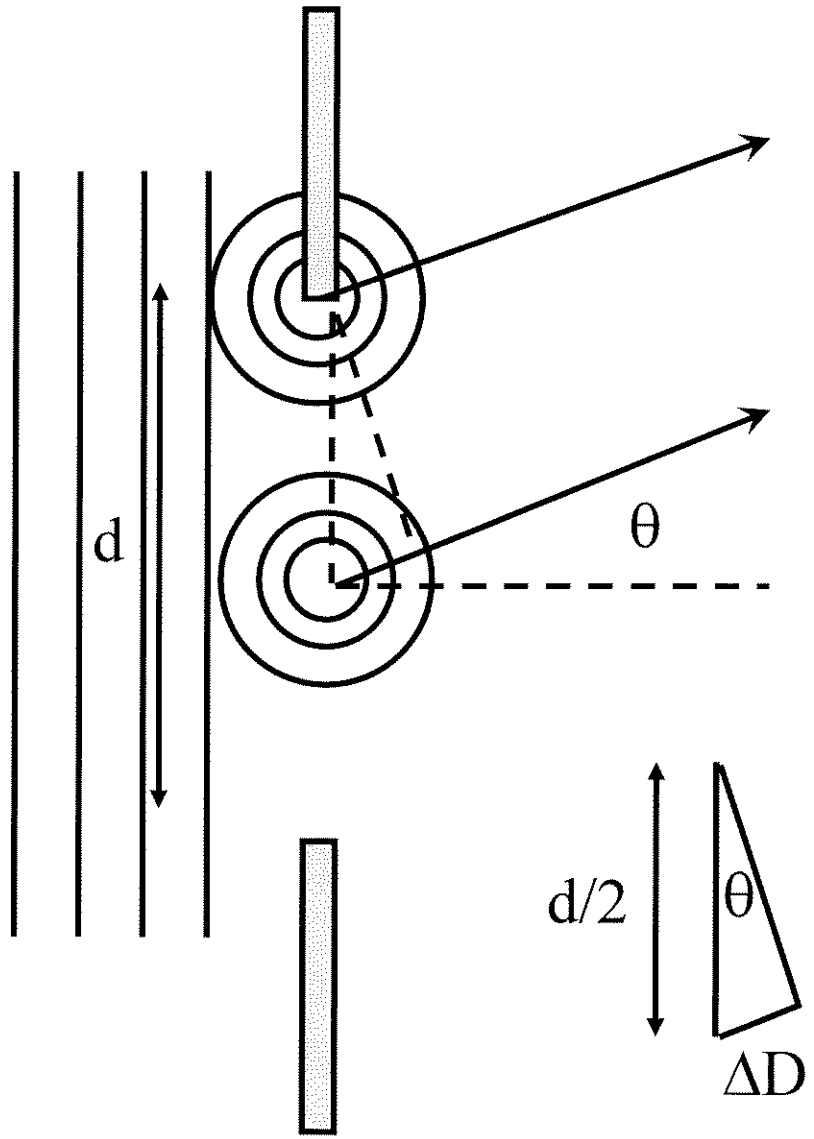
Diffraction

- What about from a single slit? We can see that the light spreads out, but not uniformly.
- To understand what happens from a single slit, we need to apply Huygens' principle within the slit itself.

Diffraction

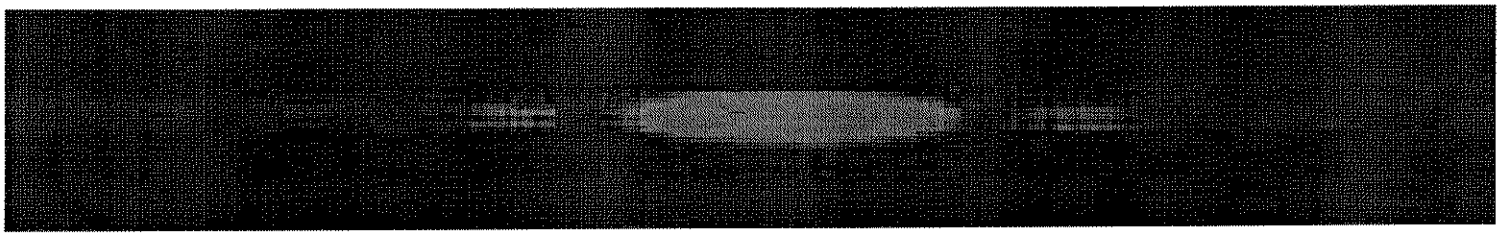


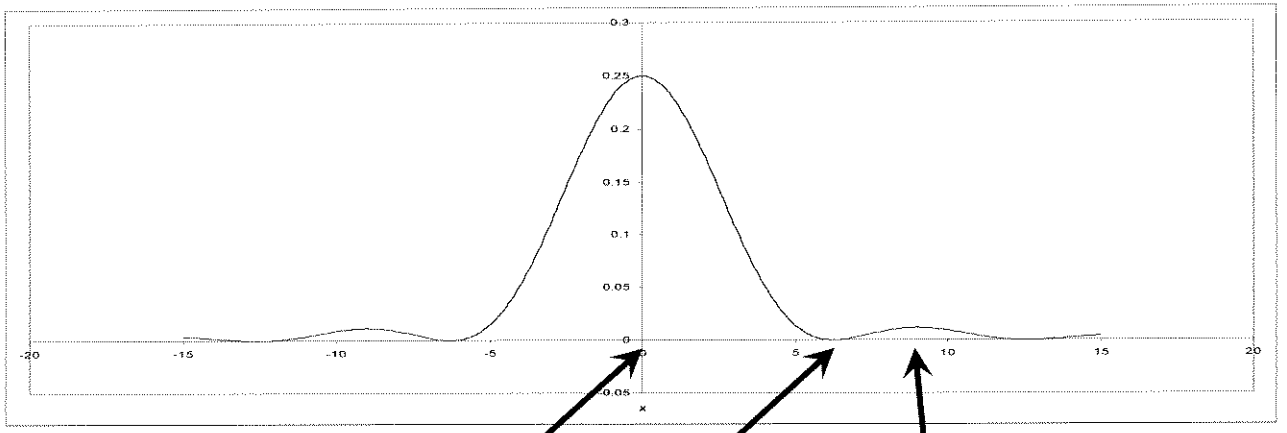
- Every bit of the interior of the slit acts as a source of outgoing spherical Huygens' wavelets.
- The outgoing wavelets from one part of the slit can interferer with the wavelets from another part of the slit.

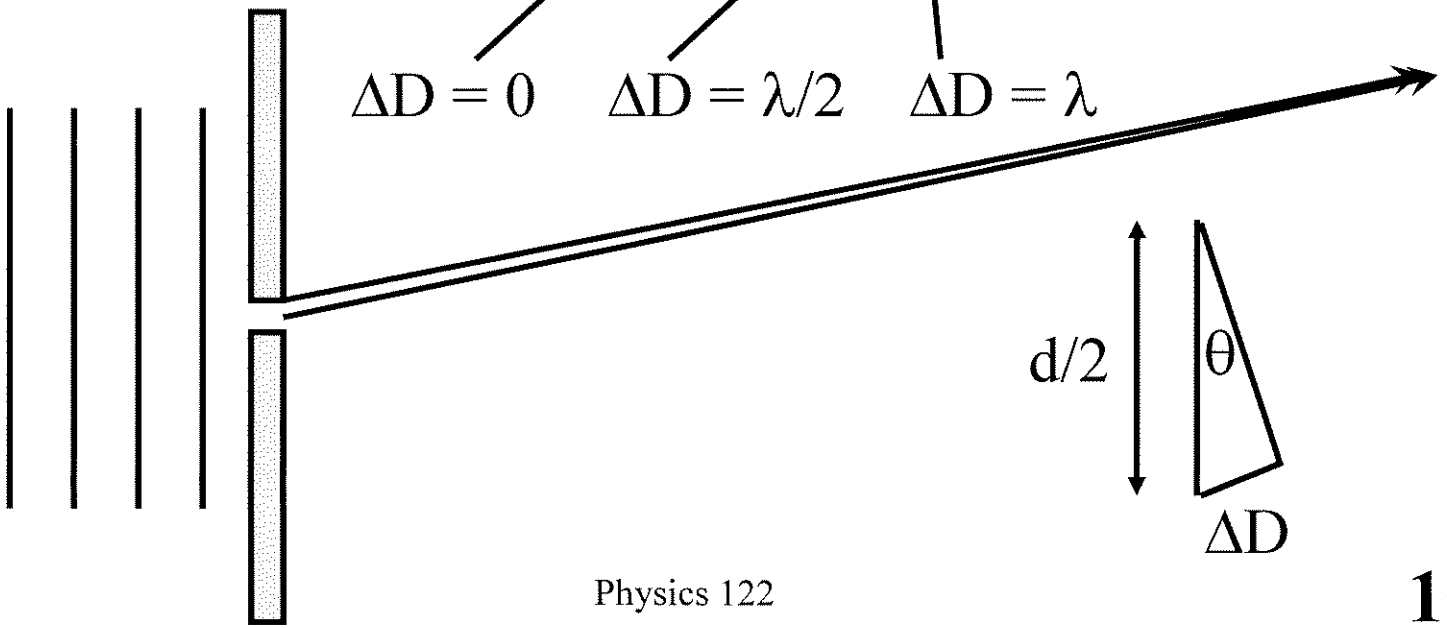


When the distance traveled by the wavelet from the middle of the slit is half a wavelength greater than the distance traveled by the wavelet from the top of the slit every wavelet from the top half of the slit has a canceling wavelet from the bottom half of the slit.

The result is no intensity at that angle.

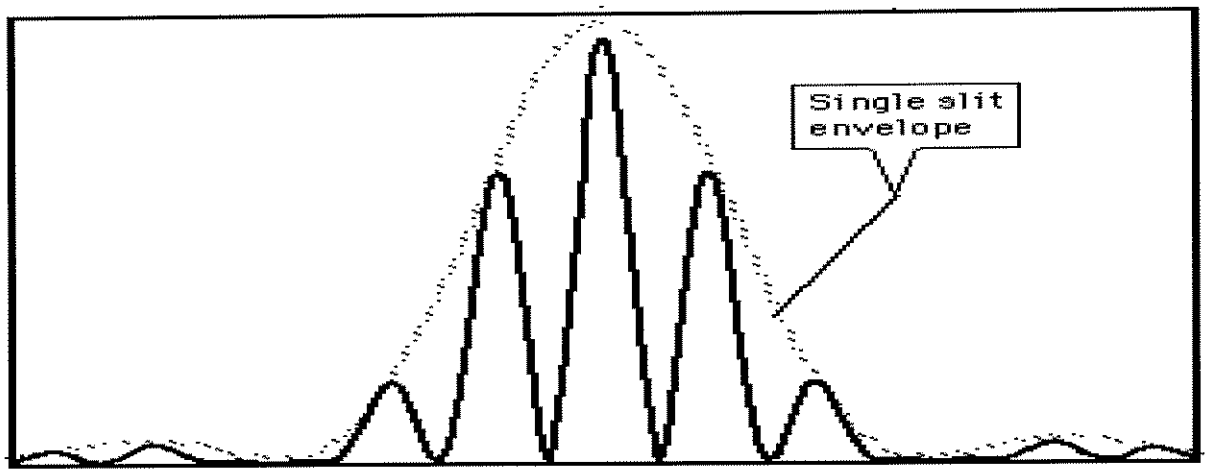



0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-20
-15
-10
-5
0
5
10
15
20
x


ΔD = 0
ΔD = λ/2
ΔD = λ
d/2
θ
ΔD

Combining interference and diffraction: 2 slits

- Even when we have two slits we have to consider both kinds of interference
  - from one slit to the other
  - within each slit.
- Both patterns are present.
- Since the width of the slit must be less than the separation between them ($d < a$ or else the two slits would overlap) the diffraction pattern is wider than the interference pattern.



$$\frac{d}{2}\sin\theta_1^{DMin} = \frac{\lambda}{2} \qquad a\sin\theta_1^{IMin} = \frac{\lambda}{2}$$

$$\theta_1^{DMin} \approx \frac{\lambda}{d} \qquad \theta_1^{IMin} \approx \frac{\lambda}{2a}$$